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THE DISTRIBUTION OF SUMMER SHOWERS OVER A SMALL AREA

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ABSTRACT

The scatter of summer showers in both time and space over the southeastern States is such that the distribution of synoptic weather reporting does not permit an accurate appraisal of the distribution of rainfall. The objectives of this investigation are to determine (1) the density of the reporting network that would be necessary to describe the areal coverage of rainfall in a given locality, and (2) the relation between this areal coverage and the average amount of rain. The localities chosen for study are Birmingham, Ala. and Atlanta, Ga., and the areas representative of these localities are defined as circles of about 50-mile radius around the Birmingham and Atlanta airports. Precipitation data used to determine the areal distribution were taken from 37 cooperative stations plus 3 first-order reporting stations in each of these areas. An analysis of these data shows, for most purposes at least, that this distribution of 40 stations provides a good indication of the precipitation coverage, and further, that an observation from one station or even the 3 first-order stations is not representative of the areal coverage. A close relationship is found between the average amount of rain per station and the areal coverage.

INTRODUCTION

Rainfall over the Southeastern States during the summer season occurs most of the time in the form of scattered or isolated showers. Some interests, such as flood control units, agricultural departments, or marketing agencies are interested in the areal coverage, whereas individual farmers are more concerned with the probability of rain occurrence. The verification of rain occurrence during this season is rather complicated if the purpose is to distinguish between days on which showers occur and those on which no showers occur. Obviously, one point of observation is not enough on which to base the distinction, because of the scatter of showers in time and space. As several questions regarding shower distribution arose during the development of an objective aid in forecasting summer rain in the Birmingham, Ala. area, it became necessary to develop some data on the subject before proceeding with the original study. The purpose of this note is to report some of the data which may be of general interest.

Specifically, three studies were made to determine: (1) the frequency of rain days in the Birmingham area, (2) the frequency of occurrence of rain at a given maximum number of stations, and (3) the relation between the areal coverage and the average amount from the stations reporting rain on any particular day.

SELECTION OF AREA AND DATA

The question of how large an area and how numerous the observation points within this area must be in order to accurately verify forecasts for the Birmingham area cannot be simply and easily answered. Some information is available concerning the average rainfall amounts over an area as determined by various spacings of the rain gages [1 and 2], but the question of rain occurrence is quite a different one and remains unsolved. The magnitude of the errors of sampling is a function of the number of measurements, which in this case may be either in time or space. Data available to determine the optimum size of the area, or the density of reporting stations within this area, are limited so that some compromise must be made initially to decrease either the period of record or the number of reporting stations available for this study. Since convective showers ordinarily move with the prevailing winds during their life cycle, considerably fewer stations would be required to determine the areal distribution of rain or no-rain over a relatively small area, disregarding the exact time of occurrence during a particular day, than to ascertain the maximum amount of rainfall near the individual storm centers. The principal interest here was in the distribution of summer showers within a circle of radius about 50 miles around the Birmingham airport, arbitrarily selected to define the Birmingham area.

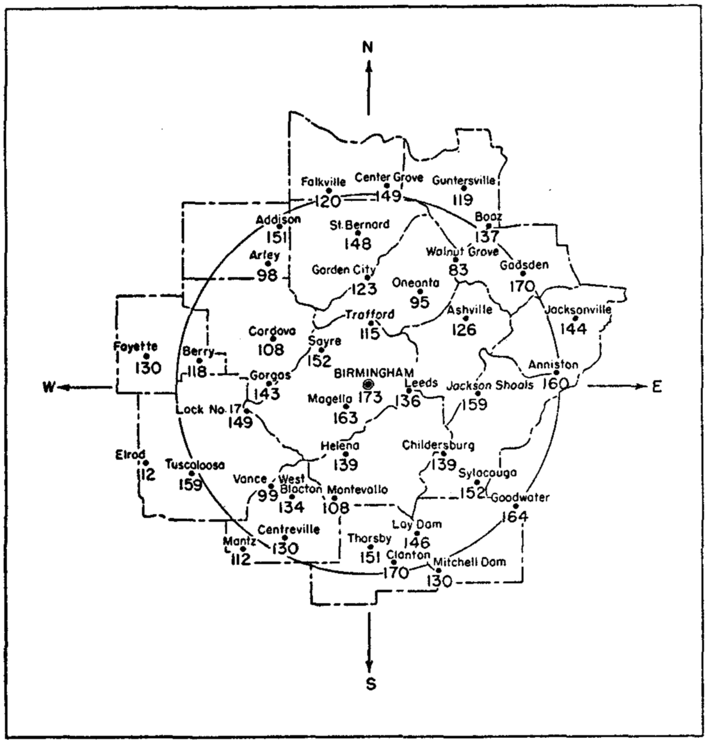

FIGURE 1.—Map showing the location of stations in the Birmingham, Ala. area and the total number of rain days for each station during the 5 summer seasons (June, July, August), 1946–1950.

After thus laying out the Birmingham vicinity, or area, all of the various stations reporting precipitation within this area which were listed in the Climatological Data [3] were examined for completeness of record during the summer season, June, July, and August. It was found that 40 stations could be utilized which had complete, or nearly complete, records during a 5-year period, 1946 through 1950, and which also reported the 24-hour precipitation amounts ending around 0700 EST, or hourly amounts so that they could be adjusted to this time. The frequency distribution of either hourly rainfall amounts or hourly occurrences for this area and season shows a very decided maximum during the afternoon and evening and with the minimum early in the morning. Since the concern is with shower days rather than the time of occurrence during the day, the period was ended nearest the time of minimum occurrence. Also, the geographic location of these reporting stations was considered in making the selection so that the stations were rather evenly distributed over the area. (See fig. 1.) Of the 40 stations used, there were four stations with six months of data missing and nearby stations which were not included among the 40 were substituted for five of these six months. There was a total of 37 dates with data from one station missing and on one date the data for three stations were missing, but in no case could incomplete data have resulted in all 40 stations reporting rain.

For the purposes of this study, the frequency of summer showers is assumed to be uniform over the area, even though full justification of this is not provided by the data, as will be shown in the next paragraph. However, the assumption is implicit in the phrasing of forecasts for this region. Most forecasters in the Southeast feel that they cannot usually predict, for a particular day, that one section of an area of this size will get rain and that an adjacent section will not. Thus the forecaster must phrase his prediction in terms of areal coverage and, if a random distribution over the area can be assumed, this amounts to a probability statement of occurrence for any particular location. It should be expected that the topographic features of the various station locations, even in an area of this relatively small size, would lead to at least small differences in the frequency of shower occurrence, but these differences are generally assumed to be unimportant.

The total number of rain days during summer over the 5-year period for each station is shown in figure 1. These data suggest that either the distribution is not entirely uniform, or that the period of record is too short. For example, Gadsen reported more than twice the number of rain days that were reported at Walnut Grove some 15 miles away. But for the most part, the differences in the total number of shower days between adjacent stations or different sections of this area did not seem unduly large. For several reasons, data on the time of occurrence of rain at some of these cooperative stations are not entirely dependable. A further check on the distribution is available through data at nearby First-Order Weather Bureau stations. The mean number of days with measurable rain was found for Montgomery, Ala., Birmingham, Ala., Chattanooga, Tenn., Atlanta, Ga., Macon, Ga., and Augusta, Ga. The length of record here varied between 52 and 80 years and these data showed no significant differences between stations. Therefore it is assumed for purposes of this study that the frequency of summer showers in this area is uniform over the area.

RESULTS FOR THE BIRMINGHAM AREA

Climatological data show that rain occurs on from 18 to 38 percent of summer days at individual stations in the Birmingham area. If the showers are randomly distributed, the occurrence of rain at one station is not indicative of showers at other stations except that the probability increases in proportion to the number of shower occurrences within the area. The relation between the percentage of rain days in the Birmingham area and the number of reporting stations within this area used in determining this percentage is shown in figure 2. The term "rain day" as employed here refers to a day in which measurable rain was reported by at least one of the stations within the group being considered. By using a single station, Birmingham airport, it was found that rain occurred on about 38 percent of the days. This compares with about 37 percent for a 55-year record. Increasing the station density to include 5 stations (Birmingham plus one from each quadrant) it was found that rain occurred at at least one of these stations on 54 percent of all days. The station density was next increased to include these 5 stations plus 5 more, and then repeated for 20 stations, 30 stations, and finally for all 40 stations. These data were entered on figure 2 and a smooth curve fitted by eye. Although the extrapolation to higher station density is rather uncertain, it is believed that there are a few days during each summer season when no rain would occur over this area, so it is reasonable to assume that this curve would not reach 100 percent regardless of the density of reporting stations. If it were possible to double or triple this number of stations (40), the number of rain days would probably increase only slightly. Indeed, the curve drawn in figure 2 suggests that data from even 30 stations would, for some purposes, adequately describe the occurrence or non-occurrence of rain days in this area. It therefore seems reasonable to conclude, at least tentatively, that this distribution of 40 stations gives a fairly good indication of the precipitation coverage, and further, that an observation from one station is not representative of whether or not showers have occurred in the area.

If it is assumed that the occurrence of rain days is adequately determined through the use of data from these 40 stations, some interesting information is available on the expected probability of occurrence of rain at a particular station. Figure 3 shows the percentage of summer days when the total number of stations reporting rain was not greater than that shown. For example, on 38 percent of all summer days during this 5-year period, the maximum number of stations reporting rain was 3 so that on 38 percent of these days no more than three stations, and usually less, actually reported rain. In this case no station reported rain on 18 percent of the days, one station reported rain on 9 percent of the days, two stations reported rain on 6 percent of the days, and three stations reported rain on 5 percent of the days, making a total of 38 percent of the days when three stations, or less, reported rain. Thus, with a perfect forecast of the percentage of areal coverage of rain, the forecaster could be certain of a correct forecast for a particular station only on those occasions when either all or none of the area would receive rain. All stations reported no rain on 18 percent of the days while all stations reported rain on less than 1 percent of all days. Considering all cases, the probability of occurrence of no-rain at a station is less than 50 percent on about 75 percent of the days while on the remaining 25 percent of the days, the probability of rain is 50 percent or greater.

It would be desirable to have further information regarding the relation between the occurrence of rain and the average amounts reported by all stations. It should normally be expected that if conditions are not favorable for numerous showers, they would not be favorable for large amounts of rain in these showers. Also, the probability of the heaviest rain from any one shower falling on one station is smaller if fewer showers occur in the area.

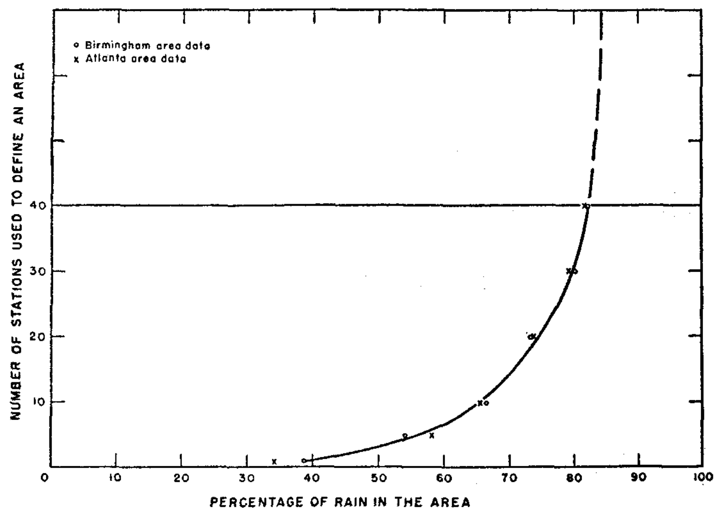

FIGURE 2.—Diagram showing the percentage of days when at least one station within a group of 1, 5, 10, 20, 30, or 40 stations reported rain. Data from both the Birmingham and Atlanta areas are for the 5 summer seasons, 1946–1950. Dashed portion of curve is extrapolated and thus uncertain.

The relation between the average amount of rain per station and the number of stations reporting this rain is shown in figure 4. The curve shown here was fitted by eye and while there is some variation in the average amount for any given number of stations reporting rain, there is a rather good relation between them. For example, when only 10 stations over this area reported rain on the same day, the average amount was about .30 inch but when 30 stations reported rain, average amounts were nearly twice as great. However, when fewer than 15 stations reported rain on one day, the variation in the average amount of rain per station and the number of stations reporting this rain is small. Whether this effect is real or due to a few errors in the data is not certain. In checking over the maximum amount reported by any one station it was found that if only one or two stations of the 40 reported rain, the amount never exceeded two inches while nearly eight inches were reported by one station on a date when 34 stations reported rain. In general, then, it appears that the relation between the average amount per station and the areal coverage for this area and season would justify the selection of either term for use in forecasting

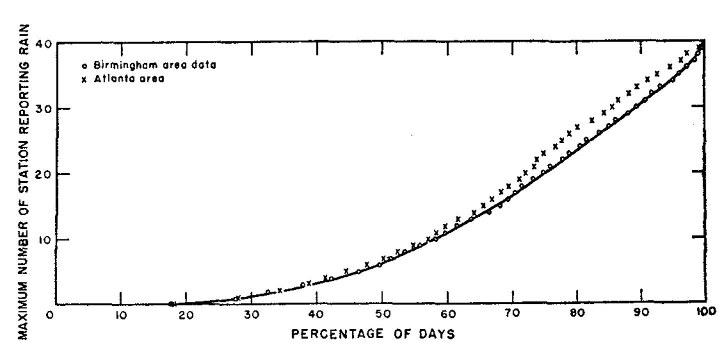

FIGURE 3.—Diagram showing the percentage of days when the indicated maximum number of stations reported rain. Data from both Birmingham and Atlanta areas are for the 5 summer seasons, 1946–1950.

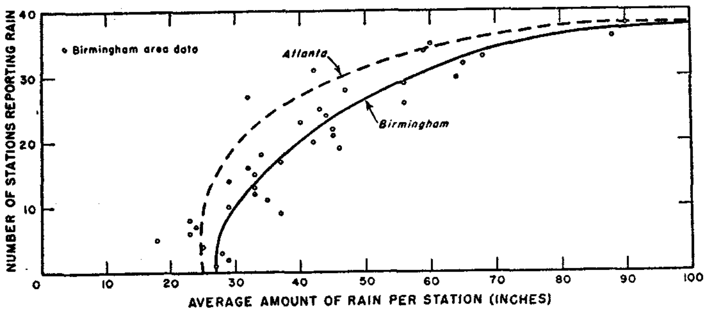

FIGURE 4.—Diagram showing the average amount of rain per station for various numbers of stations reporting rain.

or in developing some forecast aid, although a description of the distribution of rain might be preferable in most cases. Thus, this selection could be based upon operational rather than meteorological requirements.

RESULTS FOR THE ATLANTA AREA

As an additional check on the validity of the interpretations which have been made of these data in the Birmingham area, similar data were analyzed for the Atlanta, Ga., area. Again, a circle with a radius of about 50 miles around the Atlanta Airport was used to determine the area, and precipitation data were compiled for 40 stations for the same reasons as previously used. These data are plotted as circles on figures 2 and 3 and as a dashed curve, which was fitted by eye, on figure 4. The agreement in frequency of rain occurrence between these two areas as shown in figures 2 and 3 is remarkably good and tends to confirm the conclusions which were drawn from the Birmingham data. The total number of rain days in the Atlanta area over this 5-year period for each station is shown in figure 5. While slightly fewer showers occurred in this area, as well as a little less total rainfall, the differences in the total number of rain days between adjacent stations or different sections of this area are somewhat smaller than those in the Birmingham area. Thus, the conclusion that the occurrence of rain is distributed in a random manner seems to be further strengthened.

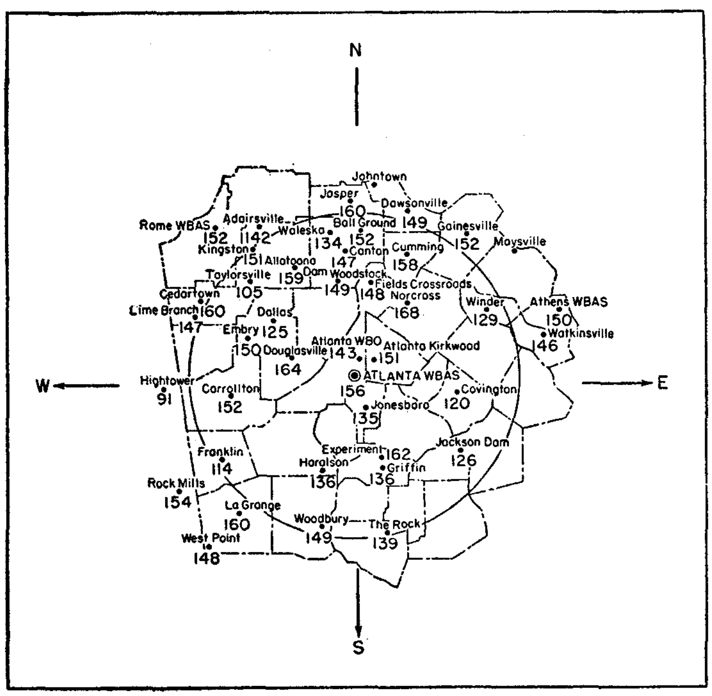

FIGURE 5.—Map showing the location of stations in the Atlanta area and the total number of rain days for each station during the 5 summer seasons, 1946–1950.

CONCLUSIONS

Figures 2 and 3 clearly illustrate that data from a single point of observation are all too frequently misleading in these areas during the summer season. The forecaster is dealing with maps which show data from many stations but in general they are located rather far apart as compared with the spacing used in this study. No more than 3 of these 40 stations in either the Birmingham or Atlanta area are available for the synoptic surface maps, and it may be noted that a value of 3 stations is located at a point on the curve in figure 3 where the percentage of rain days is changing rapidly. Thus, there must be many cases of, say, "scattered showers" or perhaps even "numerous showers" of which the forecaster is unaware simply because data on their occurrence were not available to him until weeks later. Since the maps used in his daily work do not permit an accurate appraisal of shower distribution in many cases, it is virtually impossible for the forecaster to build up a picture in his mind of exactly those conditions which subsequently result in various areal coverages of showers. This deficiency is equally important in the development of objective methods of forecasting, and this points up the importance of using all available precipitation reports when studying the forecasting of summer shower occurrence.

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